an application interface for inputting various environmental models into the computer the models comprising a tester model and system model;

a memory that contains a statistical program capable of doing statistical distribution analysis;

A4

an application interface for inputting tolerance data;

an execution unit that receives the statistical program and environmental models and processes the guardbands based on the tolerance data; and

an I/O device for outputting the guardband data .

Remarks

[1] Claims 1-27 are pending in this application. Claims 1-27 stand rejected. As a courtesy to the Examiner, the Applicants have used the paragraph structure used by the examiner to respond to the Examiners requests, objections and rejection.

Priority

[2] The applicants acknowledge that there are different inventors of this application versus the original provisional application. The provisional application was filed with "informal claims" and, obviously, a final review of inventorship could not be undertaken at that time. When the final set of claims was created another review of inventorship occurred and another inventor identified; hence, there is a slight difference between the provisional filing and the original application. However, the vast majority of inventors in the non-provisional case are as filed in the provisional application.

Oath/Declaration

[3] Apparently an incorrect older form was used that did not have the correct statutory language. Applicants acknowledge that the on the Declaration form applicants requested priority under 35 U.S.C. 120 instead of 119(e). However, the information on the declaration otherwise correctly refers to the "attached application," has the correct information for the non-provisional case, and also in the upper right hand references the internal docket number on the application on all pages of the declaration. (A PTO filing date and serial no of the non-provisional was not available at the time of filing.) This was a clerical error in that the incorrect form was used, but substantively all information necessary to connect the declaration to the application being filed and the prior application on which the case was based was on the form. Because all the important substantive information is presented in the declaration applicants request a waiver under MPEP 602.3 from the requirement that applicants submit a supplemental declaration, and a supplemental application data sheet appended hereto is provided instead to correctly identify the pertinent priority provision. (Appendix I)

If the examiner still requires that a supplemental declaration be presented, applicants ask, because of the number of inventors involved, that such be delayed until a notice of allowability is obtained.

Objections to Drawings

The Examiner has objected to the drawings on several grounds. To overcome each the Applicants have done the following:

[4-1] A new set of formal drawing are attached to this response. [4-2] In those formal drawing corrections were made to FIGS. 5 and 8 with the PRIOR ART legends as requested by the Examiner.

[4-3] Also, Applicants have amended the specification in order to overcome the objection "a" by adding in line 12 of the first full paragraph on page 7 of the double spaced version of the specification a reference number 56 after the phrase "for each performance sort or system." Additionally, to overcome objection "b" the Applicants have added on line one of the first full paragraph, after the phrase "the models previously described as blocks" the reference number 100. These inclusions are clear in terms when reading the text against the respective figures.

Specification

[5] Applicants have submitted a substitute specification. (Appendix II) Additionally, a redlined version of any pages that were amended by this response are provided for the Examiner's convenience.

Claim Rejections – 35 U.S.C. 112, 1st Paragraph

[7] The Examiner has rejected the application under 35 USC 112, first paragraph, arguing that there is a substantial lack of teaching for the claimed invention.

First the Examiner claims that the how to "combine the individual values and then add hot-e input based on performance sort" has not been described in the specification. The original specification on page 5, lines 3-11 teaches how to determine hot-e guardbands based upon several variables including speed sort via the average channel length at a particular speed sort. It is well known that hot-e degradation is directly related to the channel length of the device, duty cycle, operating voltage and operating temperature. Page 5, lines 17-21, teaches selecting one guardband value from each model for each iteration of the Monte Carlo analysis and then adding a hot-e guardband which corresponds to performance sort. As previously discussed in the specification performance sort is equivalent to speed sort (see page 3 lines 15-21) upon which the hot-e model is based.

Secondly the examiners states that ere is no description of a Monte Carlo analysis and how it is used. Steps 160, 170, 180 and 190 of Figure 7 illustrate a typical Monte Carlo analysis. Additionally, page 5, lines14-24, describe how a Monte Carlo analysis is

utilized in the invention. The process of randomly selecting guardband values from the various models to form a single overall guardband value, this process being repeated a number of times to form a distribution of guardbands, is described. Figure 2 illustrates this distribution of guardbands determined using the previously described Monte Carlo technique. Finally, the Monte Carlo analysis itself is well known in the art.

Claim Rejections – 35 U.S.C. 112, 2nd Paragraph

[9] The Examiner rejected claims 2-4, 6 and 12-26 under 35 USC 112. The Applicants have amended the claims to overcome the Examiner's rejections.

Claim Rejections – 35 U.S.C. 102

[11] The Examiner rejected claims 1-4, 6-7, 20-24 and 27 under 35 USC 102(b) as being anticipated by Mittle et al., U.S. Patent 5, 634,001 issued May 27,1997 ("Mittle").

In general, Mittle does not teach or suggest modeling the tester environment or end-system environment in which the microprocessor will reside. Mittle teaches a method of determining a hot-e guardband by taking into consideration circuit timing data, operating voltage and case temperature as well as the voltage / frequency response of a microprocessor. Mittle does not teach or suggest modeling variations within the tester or

system environment. Mittle does not teach or suggest using a Monte Carlo analysis to determine an overall product guardband. Mittle restricts its teaching to the calculation of a hot-e guardband which is only one consideration of the present invention. Mittle also fails to teach or suggest selecting a final guardband based upon market quality expectations.

The Applicants will now address in terms of the claims why Mittle does not teach what is claimed by Applicants. All references are made to the originally filed specification, not the substitute specification provided herein.

[11-1, 2] Particularly, Mittle does not teach or suggest modeling of system variables. Instead, Mittle only considers a nominal operating voltage and temperature at which a microprocessor is expected to operate when determining a hot-e guardband. Therefore Mittle does not teach "creating a set of **distribution** models representative of variables" in claim 1. Mittle fails to teach or suggest modeling of **system** voltage and temperature **variables** (claim 2). It is well known that voltage and temperature do not remain fixed at a certain value. Voltage regulators and thermocouples have a distribution about which they function. For example, a voltage regulator may have a nominal operating value of 2.0V with a range of +/- 100mV. Mittle et al. fail to take this distribution into account when determining a hot-e guardband. Similar distributions exists for many factors such as the tester upon which a circuit is tested (including both mechanical and electrical variations) as well as variations within the end system.

[11-3] Mittle does not disclose a test system as a variable. Mittle simply determines the difference expected in a microprocessor's performance between beginning of life (BOL) and end of life (EOL). Mittle does not teach or suggest that the test environment upon which a microprocessor is tested should be modeled to account for variations within that system. Hence there is no teaching of a variable for "system to tester offset" as set forth in claim 3.

[11-4] Mittle discloses circuit-level timing analysis. This is based upon a simulation of a particular circuit. Mittle does not teach or suggest the use of a tester to determine actual circuit performance. A simulation environment on a computer does not inject variations into guardband determinations as does an actual tester environment. An actual tester environment introduces many variations as a result of both electrical and mechanical components. These components do not exist when simulating circuit performance, and thus there is no need to model variations that may exist in a tester environment. So there is no teaching of using the "test system" as a variable (claim4).

[11-5] Yes, Mittle does disclose the specification as maximum frequency. However, the arguments with regards to claim render claim 6 allowable.

[11-6] Mittle does not teach or suggest a sample of at least 10. In fact, there is no sample size requirement in Mittle. The part of Mittle cited by the Examiner discusses a histogram of propagation delays for all the paths of a microprocessor. There is no

sampling as set forth in claim 7, just simply a graphical representation of the delay associated with each path of a microprocessor.

[11-7] Although Mittle does use a reliability wearout model it does not teach or suggest the use in the context of this invention; i.e., of a "set of distribution models representative of variables that affect the specification." So claim 10 is allowable in view of how it the model is used.

[11-8] The Examiner notes that claims 20-24 have similar limitations to those in claims 1-4. Therefore the arguments overcoming anticipation for those claims apply equally well to claims 20-24.

[11-9] Again, Mittle fails to teach or suggest a system that uses various models that represent the tester or system environment. (i.e. the description for the application interface in claim 27). Furthermore, Mittle fails to teach or suggest an application interface for inputting various models into the a computer comprising a system model and a tester and system . Mittle also fails to teach or suggest the system that uses the analysis program to determine an overall system guardband from the model inputs.. (i.e., an **execution unit that receives** the statistical program and **environmental model**s and processes the guardbands based on tolerance data. The Examiner cannot point to desperate elements with obviously different connotations within a reference and somehow equate them to what is claimed by applicants. (See general discussion above about what Mittle does provide and its contex.

[12] The Examiner also claims 1-4, 6-9, 20-23 and 27 under 35 USC 102(b) as being anticipated by Conrad, et al., Calculating Error of Measurement on High Speed Microprocessor Test," Proceeding of International Test Conference, October 1994, pages 793-801 ("Conrad").

General: The Conrad reference only addresses the tester environment for a processor. The goal of the Conrad reference is to provide more accurate testing means for measuring the performance of the processors and errors that may be introduced by these differences. It uses a heuristic/experimental approach in doing so. So Conrad does not teach or suggest modeling of the variations within a system. Furthermore, Conrad fails to teach or suggest tester-to-system offset. Conrad also does not mention the use of a Monte Carlo analysis to determine an overall system guardband by iteratively selecting guardband components from each of the variables modeled. Finally, Conrad does not teach or suggest the modeling of reliability wearout mechanisms (such as hot-e degradation) nor does Conrad teach or suggest selecting a final guardband based upon market quality expectations.

The Applicants will now address in terms of the claims why Conrad does not teach what is claimed by Applicants. All references are made to the originally filed specification, not the substitute specification provided herein.

[12-1] Conrad is far removed from what is claimed in claim 1. Like Mittle there is no teaching of creating **a set of distribution models** representative of variables and analyzing the set using a statistical tool. The Examiner broadly cites the entire paper for this concept. A close reading of what Conrad teaches is that there is tester variation through the results of an "experiment." This experiment is based on the use of different testers and methodologies. See page (See "Test Process Improvements" and "Summary," Pages 797-798) This is just a small part of what applicants teach (see page 3, lines 23-26) and certainly not what applicants claim in claim 1. Conrad does not teach a methodology obtained by using the results (like those obtained by Conrad) to create distribution models of variables and then applying them to a **statistical** tool and then produce a guardband based on the statistical analysis and tolerance targets (claim 1). There is no evidence of such at all in Conrad.

[12-2] The Examiner cannot ignore the plain meaning of claim 2, "the system on which the product is used." This is clearly not a "test loadboard." See page 4, lines 6-25, of the specification for further explanation.

[12-3] There is no teaching in Conrad of a "tester **offset**" being used as a variable in a distribution model. A tester offset is not the test **method**(s) referred to in Figure 4. Again, the Examiner provides no rational why the obvious differences in language and connotation should be ignored. See page 5, lines 10-14.

[12-4] Although the experiment structure of figure 1 could arguably comprise "a test system," there is no teaching in Conrad of using the test system as one of the **variables** in a set of distribution models as claimed by applicants in claim 4.

[12-5] Although Conrad speaks of maximum frequency, claim 6 is otherwise allowable over Conrad since it depends on claim 1. (See arguments in 12-1 above.)

[12-6] Although Conrad performs "experimental" sampling, there is no apparent teaching Conrad of using such samples for creation of "models," let alone a set of distribution models. So claim 7 is clearly not anticipated.

[12-7] Applicants disagree with the Examiner that the "scrap risk," a computation created in comparing two different testers somehow teaches using "quality as a tolerance target" within the meaning of Applicant's invention. Conrad seems to teach a balancing of something called consumer risk versus scrap risk to help her heuristicly determine guardband. (See the discussion in Conrad below Table 1.) So claim 8 is not anticipated.

[12-8] The arguments regarding scrap risk above seem to equally apply to "revenue target and down bin risk." Although the terms maybe be somehow indirectly linked, it is certainly applied differently in Conrad than is claimed by Applicants. Co claim 9 in not anticipated.

[12-9] Since the Examiner, equates the limitations of claim 20-23 with claims 1-4, the arguments above regarding why the Conrad reference is not anticipatory apply equally well to claims 20-23, and they are clearly not anticipated.

[12-10] No where in Conrad is there any mention of application interfaces having certain attributes. Figure 1 as noted in Conrad is an experiment structure. This is far from the plain meaning of an application interface. So Claim 27 is clearly not anticipated.

In lieu of the above arguments, it is clear that neither Mittle or Conrad teach what is claimed by Applicants.

Claim Rejections – 35 U.S.C. 103

[14, 16] Claims 5 and 25 are rejected under 35 USC 103(a) in view of Mittle and Applicants assertion. The same claims were rejected on similar grounds, using Conrad as the primary reference instead of Mittle.

[14-1] Even if it would be obvious to use a Monte Carlo analysis in light of Mittle, this is irrelevant because Mittle teaching is limited to how to determine a guardband for reliability wearout mechanisms. Mittle fails to suggest the use of models that are representative of variables in a specification. See discussions regarding claims 1 and 20 above. As to the Monte Carlo analysis, Mittle actually teaches away from the use of a

Monte Carlo analysis because such an analysis would inject unnecessary uncertainty into the guardband calculation. The techniques taught in Mittle have no use for a statistical sampling technique like that taught and claimed by Applicants. Statistical sampling may actually cause excessive variation in the hot-e guardband calculation, thus rendering it ineffective. Monte Carlo analysis is suited for applications where a probabilistic approximation to a solution is desired. Mittle teaches how to determine an exact guardband based upon circuit timing analysis, operating voltage and temperature and channel length. A probabilistic approximation is not desirable in this situation because nothing needs to be approximated.

Applicants assertions regarding the variability of the type of statistical analysis tools in its own claimed invention has nothing to do as to whether it would be obvious to include such tools in Mittle.

An argument similar to the above could be made with respect to Conrad. See the 102 analysis regarding claims 1 and 20
Since the Examiner has failed to establish that Mittle or Conrad reads on claims 5 and 25, let alone the claims upon which they depend, the Examiners 103 arguments with respect to those claims fail.

[15, 17] The Examiner has rejected claims 11 and 26 under 35 USC 103 as being unpatentable over Mittle ii\n view of Kreyszig, "Advanced Engineering Mathematics," John Wiley & Sons, 1988, pages 1248-1253 ("Kreyszig"). Also the Examiner has

rejected the same claims on similar ground to the one presented in section 15, instead using Conrad as the primary art.

With regard to the remaining 103 rejections, the combinations cited by the examiner fail to suggest three of the novel aspects of the present invention set forth in claims 11 and 26. First, there is no suggestion of the use of "distribution models representative of variables that affect a specification." Furthermore, there is no suggestion that the distribution models should be analyzed using a statistical tool. The cited art only deals with individual components of a guardband (reliability wearout mechanisms in Mittle and the tester environment in Conrad). There is no suggestion as to how one would determine an overall guardband based upon reliability wearout mechanisms as well as variations within both the tester and system environment. Finally, there is no suggestion to select a final guardband based upon a statistical analysis.

For these reasons claims 11 and 26 are clearly patentable over the prior art.

[18] In conclusion, in lieu of the amendments to overcome the 35 USC 112 rejections, claims 1-27 are in conditions for allowance and are clearly allowable over the prior art.

SUMMARY AND CONCLUSION

In view of the foregoing, withdrawal of the rejections and the allowance of the current pending claims is respectfully requested. If the Examiner feels that the pending

claims could be allowed with minor changes, the Examiner is invited to telephone the undersigned to discuss an Examiner's Amendment.

Respectfully submitted,

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STATISTICAL GUARDBAND METHODOLOGY

Cross Reference to Related Applications

This application is based on Provisional Application Number 60/172,198, filed on December 17, 1999.

Field of the Invention

This invention relates to methods and systems used to develop guardbands for assessing product specifications. More particularly it relates to methods and systems for developing guardbands for integrated circuits such as processors which are subject to manufacturing, testing and environmental performance variations.

Background of the Invention

Guardbands are typically used in manufacturing to protect against product and process specification variations. However, if a manufacturer is too conservative in setting the guardband the amount of good products that fail testing is increased. If the guardband is too narrow, the products that go to customers may not function as specified. Two articles that discuss guardbands and the tradeoffs due to guardband placement are *The Economics of Guardband Placement*, Richard Williams and Charles Hawkins, International Test Conference 1993 and *The Effect of Guardbands on Errors in Production Testing*, Richard Williams and Charles Hawkins, International Test Conference 1993.

Products, especially, integrated circuits, are designed to be used in a number of applications. Each application often provides a somewhat different set of operating conditions.

To insure that the product can work in each of these applications manufacturing tests must be created to test both for these operating components and the surrounding impact of system

repeated. If the processor booted and ran all software without hanging, the FMAX is recorded at step 33. This process is repeated at step 37 for another voltage, temperature, PLL mode or processor. When process is complete, the FMAX data for the system environment are characterized at step 39 and included with the tester models.

Once product FMAX data is collected on a given number of integrated circuits, both on a tester and in a system, that data can be analyzed to determine the system-to-tester offset model. Based on various products studied, in gathering system and tester data best results occur by sampling at least 15 to 20 processors per performance sort.~~generated.~~ At step 50 the system and tester FMAX data is input into the statistical software program. At step 52 a system-to-tester FMAX delta is calculated. This delta at step 54 is tested for best distribution type (typically, the distribution is Gaussian). Based on best distribution fit, at step 58 distribution parameters are calculated based on sample size and confidence selected at step 60 (for Gaussian distribution, population mean and standard deviation are estimated). For a Gaussian distribution, a t-distribution is used to estimate population mean and chi-squared distribution is used to estimate population standard deviation. These results are output to the Monte Carlo routine at step 62. This process is repeated through step 64 for each performance sort or system *56* under analysis until *the* process is completed at step 66.

Reliability wearout mechanisms are estimated using both technology models and product specific data (power on hours, use voltage, use temperature, etc.). Depending on the wearout mechanism, different parameters will drive guardband. In the case of processor's hot electron (hot-e) degradation is an important specification., However, this technique could be extended to cover other reliability wearout mechanisms (i.e. SER, electromigration, etc.). A hot-e guardband model is developed using technology models (design manual equations, circuit models, etc.) and

product specific variables such as operating voltage, operating temperature and average channel length per speed sort. This model predicts performance degradation at end of life. Hot-e is primarily driven by high voltage and short channel length. As illustrated in FIG. 6 fail rates increase on axis 15 with frequency (shorter channel lengths) and on axis 13 with voltage. This reliability data is characterized by the statistical software program to form a reliability model.

As illustrated in FIG. 7 the models previously described~~denoted~~ as blocks *100,* 110, 120, and 130 are inputs to the Monte Carlo analysis as well as market sector quality (i.e. SPQL) expectations denoted as block 140. Each model is incorporated using the distribution type determined during the analysis previously described. A loop value is set (shown as 10,000, in block 150 but can be any relatively large number). Each model contributes a value at step 160 which is randomly selected based on distribution type. One guardband value is determined by combining the individual values and then adding hot-e input based on performance sort. This is repeated through steps 180, 190 and 170 until the loop value selected in block 150 is reached. The output is a distribution of guardbands based on all factors previously discussed. Finally, depending on market quality expectations input at block 200, a guardband can be selected at 210 which intelligently satisfies market tolerance expectations while minimizing yield loss (See Figure 2). As can be seen from Fig. 2, trimming a few percent off a guardband , shown as vertical axis 4, to make yield targets without understanding the effects on product quality may adversely effect product quality. The opposite holds true as well. Over-guardbanding can lead to quality levels not required in the market which can in turn adversely affect yields and revenue.

As mentioned earlier any statistical software program can be used with the invention. SAS is used in the current implementation, but other programs are just as good (i.e. MATLAB, MATHCAD, etc.). One also uses these statistical software programs when determining the